5.1 Fat-Soluble Vitamins

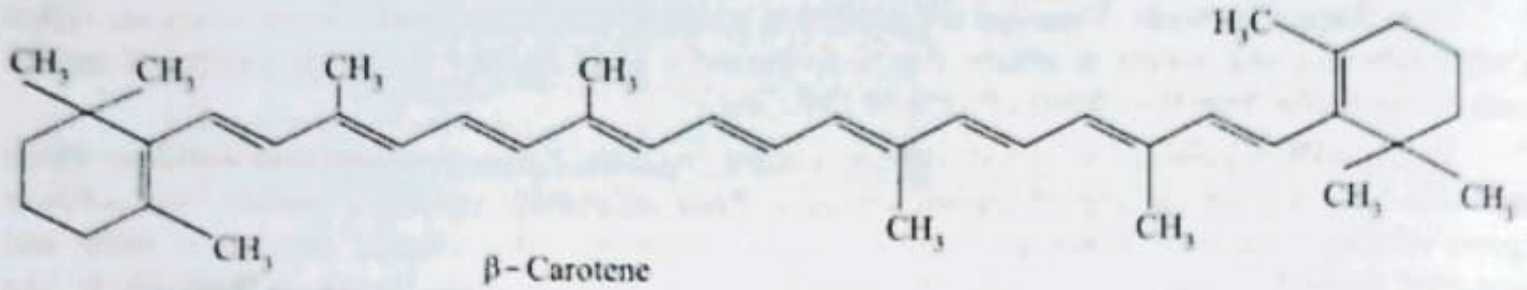
Fat-soluble vitamins are generally associated with fatty foods, such as butter, cream, vegetable oils and fats of meat and fish. These substances generally contain only traces of B vitamins. None of the fat-soluble vitamins contain nitrogen in their structure. They are more stable to heat than the B vitamins and are less likely to be lost during the cooking and processing of foods. They are absorbed from the intestines along with fats and lipids in foods. As already stated they are not excreted in the urine and get stored in the body to a considerable extent, and this can result in toxicity.

5.1.1 Vitamin A

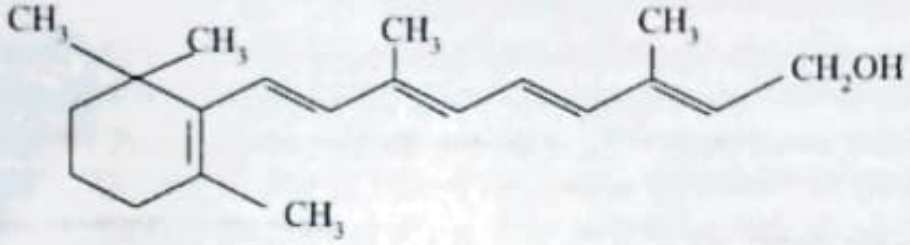
Vitamin A is found in animal materials like meat, milk, fish, etc. In animals, the vitamin is found in highest concentration in the liver, where it is stored and exists generally as a free alcohol or its esterified form. Plants do not contain vitamin A, but contain its precursors (provitamin A), the carotenoids, which are converted to vitamin A after absorption by the ingesting animal. Carotenoids are the orange and yellow pigments of fruits and vegetables. Green leafy vegetables also contain carotenoids; in these, the green colour of chlorophyll masks the yellow carotenoids.

Vitamin A is an alcohol ($C_{20}H_{29}OH$). It has been named "retinol" because of its specific function in the retina of the eye. Metabolically active forms of the vitamin include the corresponding aldehyde (retinal) and the acid (retinoic acid).

carotenes (α -, β -, γ -carotenes) and cryptoxanthin occur widely distributed in nature. β -carotene has a symmetrical structure and the molecule splits into half to give two molecules of vitamin A.



β - Carotene



Vitamin A alcohol (Retinol)

Vitamin A is fairly stable to heat, but prolonged heating in contact with air destroys it. It is easily destroyed by oxidation and ultraviolet light. Fats and oils lose their vitamin content by oxidation as they become rancid. Anti-oxidants prevent the loss of vitamin A by oxidation.

Until recently the vitamin A activity in foods was expressed in international units (IU); 1 IU being equivalent to 0.3 μg of retinol or 0.6 μg of β-carotene. Because of the considerably poorer utilization of dietary provitamins when compared with retinol, the FAO/WHO Expert Committee has decided to abandon the expression of vitamin A value of foods as IU and proposed that vitamin A activity be stated as the equivalent weight of retinol (retinol equivalent, RE). By definition, one retinol equivalent is equal to one μg of retinol or 6 μg of β-carotene, or 12μg of other provitamin A carotenoids. In terms of IU, one retinol equivalent is equal to 3.33 IU of retinol or 10 IU of β-carotene. The recommended daily allowances for adult males is 1,000 retinol equivalents and that for adult females 800 retinol equivalents.

Functions: Vitamin A is essential for night vision. The retina is the layer of light sensitive cells lining the back inside of the eye, consisting of rods and cones. Cones respond to light by day and rods by night. Rods contain the photosensitive pigment rhodopsin (visual purple). The pigment is composed of a protein called opsin bonded to a molecule of retinal. The pigment is photosensitive. When light falls on the retina, oxidation–reduction of retinol–retinal and stereochemical changes of vitamin A molecules (11-*cis* retinal to all *trans* retinal) take place. When there is a deficiency of vitamin A the rods cannot adjust to light changes, resulting in night blindness.

One of the chief functions of vitamin A is to maintain the health of epithelial cells, namely, the skin and membranes that line all passages that open to the exterior of the body, as well as glands and their ducts. These cells secrete mucous which coats and protects them against invasive micro-

role played by these membranes in protecting the body against infection. It is from this function that vitamin A has become known as the anti-infective vitamin.

Vitamin A is also necessary for the growth and development of skeletal and soft tissues through its effects upon protein synthesis and differentiation of the bone cells. It is also required for the proper formation and maintenance of tooth enamel and healthy gums.

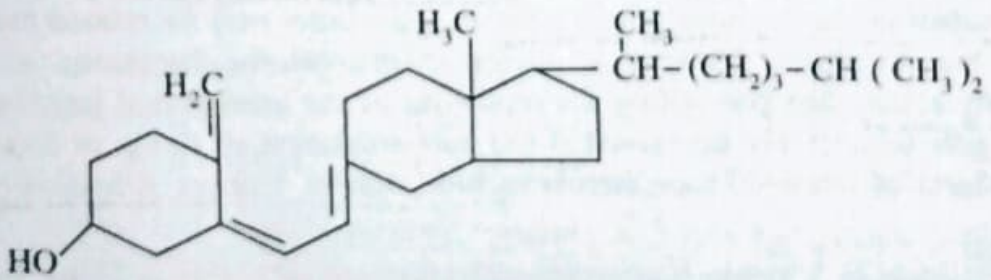
Deficiency disorders: Prolonged deficiency of vitamin A may produce skin changes, night blindness and corneal ulceration. In extreme deficiency states, the mucous membranes of the respiratory, gastrointestinal and genitourinary tracks do not function normally and are less of a defence against infecting organisms. Night blindness is attributed to the functional failure of the retina in the proper regeneration of visual purple. Vitamin A deficiency can lead to keratinization of the cornea, resulting in xerophthalmia. This is an important cause of blindness in poorly fed children in developing countries like India. Vitamin A deficiency results in the skin becoming dry, scaly and rough (xeroderma).

5.1.2 Vitamin D (Calciferol)

Rickets or osteomalacia is a bone disorder and it also occurs as a result of calcium and phosphorus deficiency. Cod liver oil has been used to cure this disease since the Middle Ages. It was noticed in the 1920s that when certain foods are exposed to ultraviolet light, they develop the ability to protect animals against rickets. Vitamin D isolated in crystalline form was named calciferol.

Most foods are low in vitamin D, although it is found in small quantities in butter, cream, egg-yolk and liver. Milk is a poor source of vitamin D; therefore, in some countries milk is fortified with this vitamin. The best food sources of vitamin D are fish liver oils.

There are at least 10 sterols which are provitamins D. Two major sterols that are converted into vitamin D by the action of ultraviolet light are the plant sterol, ergosterol, which gives ergocalciferol (vitamin D_2) and 7-dehydrocholesterol from animal tissues, which gives cholecalciferol (vitamin D_3). Vitamin D is remarkably stable and preparations of foods containing it can be warmed or kept for long periods without its deterioration. Storage, processing and cooking do not affect its activity.



Vitamin D_3 (Cholecalciferol)

Function: Like other fat-soluble vitamins, vitamin D can be stored in the body to a large extent. The overall function of vitamin D is to produce a vital hormone called 1, 25-dihydroxycholecalciferol (1, 25-dihydroxy D_3 or vitamin D_3 hormone). This is formed by the liver and kidney, and the hormone is essential for the overall effects of dietary vitamin D, which include promotion of growth and proper mineralization of the bones and teeth. Vitamin D increases the intestinal absorption of calcium, phosphate transport in the intestines, maintains proper calcium and phosphorus levels in the serum and increases the reabsorption of calcium by the kidney.

Deficiency: The deficiency of vitamin D in children during the period of active skeletal growth causes rickets, which results from the defective mineralization of the ends of the growing bones. As a

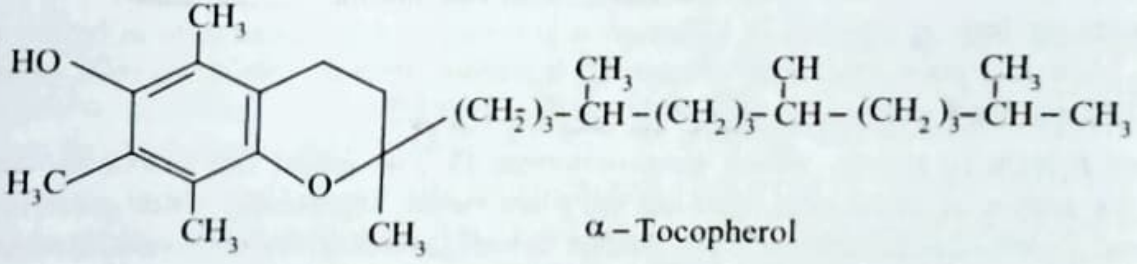
is decalcification of bone shafts and the tendency is for fractures rather than bending to occur.

One international unit of vitamin D is defined as the activity contained in 0.025 mg of cholecalciferol. For infants, children and adolescents a daily allowance of 10 mg is required for better calcium absorption and some increase in growth. With cessation of skeletal growth, the requirement for vitamin D decreases; an allowance of 5 mg could do after 22 years. During pregnancy and lactation, an additional allowance of 5 mg over the non-pregnant allowance is required.

5.1.3 Vitamin E (Tocopherol)

Vitamin E is the most widely available of the vitamins in common foods. Wheat germ oil is the richest source of the vitamin. It is also present in other cereals, green plants, egg-yolk, milk-fat, butter, meat, nuts and vegetable oils (soyabean, corn, cottonseed).

Vitamin E activity in food derives from four tocopherols (α-,β-,γ- and δ-) and four tocotrienols. α-tocopherol is biologically the most active form of vitamin E. The other compounds (β-γ-, and δ;-tocopherols and α-, β-,γ-and δ -tocotrienols) have lower biological activities, estimated to be 1–50 per cent of α-tocopherol.



α – Tocopherol

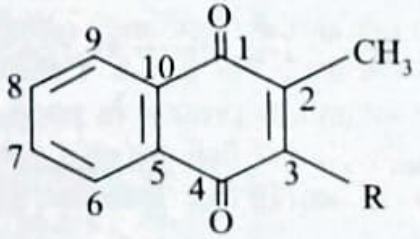
The most important chemical property of vitamin E is its anti-oxidant property. However, the most potent anti-oxidant is not the most potent vitamin. This latter may be related to the absorption of

tocopherol acetate. The activity of 1 mg of naturally occurring α-tocopherol is 1.49 IU. Now vitamin E activity is referred to in terms of milligrams of α-tocopherol equivalents.

The recommended daily allowance of vitamin E for infants is 3–4 mg α-tocopherol equivalents (α-TE), for children and adolescents, 10 mg α-TE and for adult males and females 7–13 mg α-TE. During pregnancy and lactation, an additional 2–3 mg α-TE is recommended.

5.1.4 Vitamin K

Two forms of vitamin K occur naturally—vitamin K_1, (phylloquinone) in green plants and vitamin K_2 (menaquinone) which is formed as a result of bacterial action in the intestinal tract. Water-soluble forms of K_1 and K_2 are available for use by individuals unable to absorb the fat-soluble form. The K vitamins are naphthoquinone derivatives and differ from one another in the length and type of their side chains



Vitamin K

$$K_1, R = -CH_2-CH=\overset{CH_3}{\overset{|}{C}}-CH_2-(CH_2-CH_2-\overset{CH_3}{\overset{|}{C}}H-CH_2)_3-H$$

$$K_2, R = -(CH_2-CH=\overset{CH_3}{\overset{|}{C}}-CH_2)_n-H$$

Menadione (2-methyl-l, 4-naphthoquinone, vitamin K_3) is a fat-soluble synthetic compound and is about twice as potent biologically as the naturally occurring K_1, and K_2 on a weight basis because it lacks the long side-chain of the natural vitamin. Menadione is a provitamin and a side-chain in position 3 is to be introduced before it becomes biologically active and this takes place in the body.

The best sources of vitamin K are green leafy vegetables, especially spinach, cabbage and lettuce. Fruits, cereals, dairy products and meat provide lesser amounts. An average mixed diet provides 300-500 μg of vitamin k daily. Half of the vitamin K in man is of intestinal origin synthesized by the gut flora and half is phylloquinone. Deficiency of this vitamin is uncommon in adults. New-born infants before establishment of intestinal flores show a deficiency.

Because of the synthesis of vitamin K by intestinal bacteria in normal individuals, no specific recommended allowance is made for this vitamin. To be safe, a daily allowance of 12–20 μg for infants, 20–40 μg for children, 50–100μg for adolescents, and 70–400 μg for adults, is recommended.